Basics of a Good Road - Concrete Pavements

Road Scholar Program

Part II

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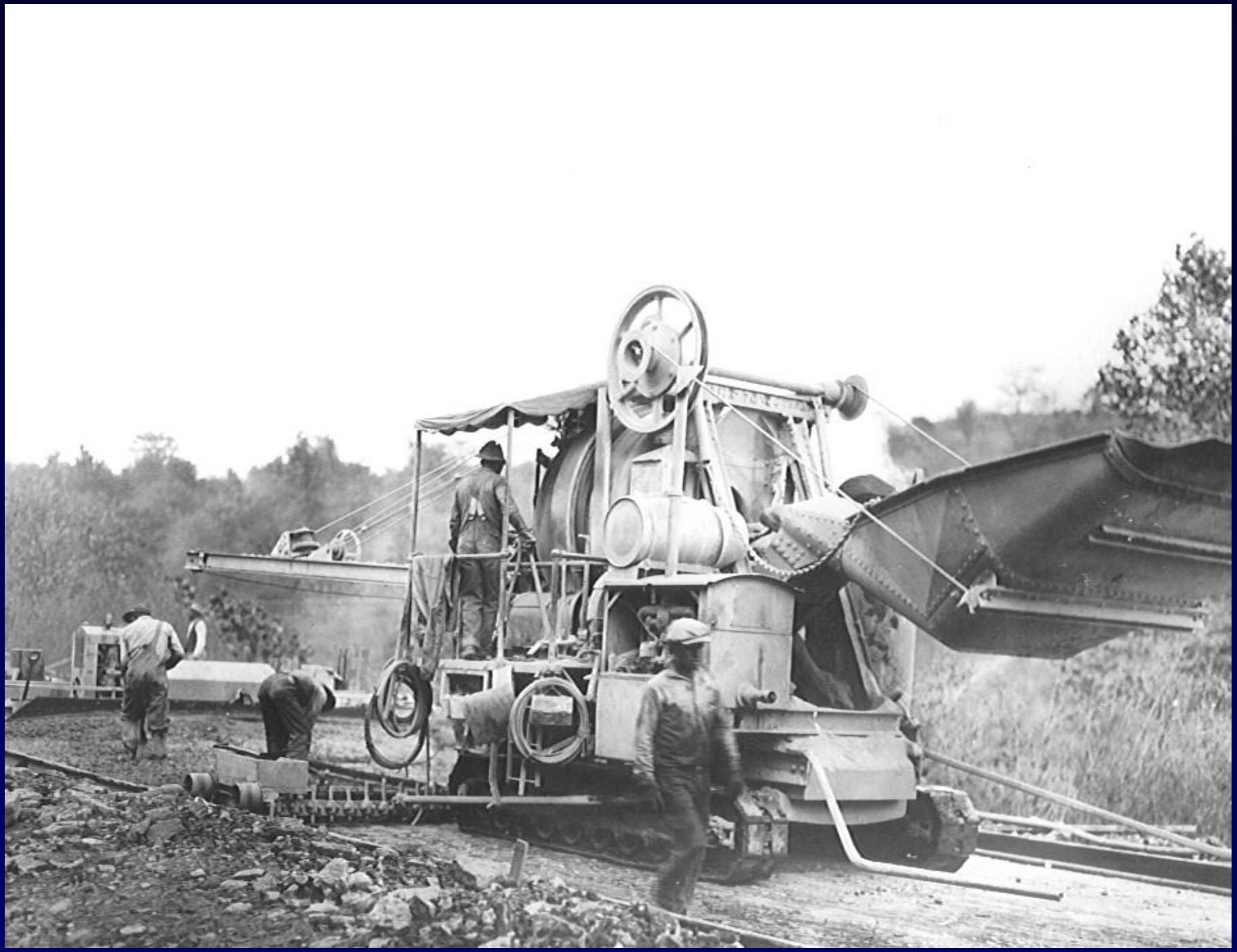
Indiana Chapter – American Concrete Pavement Association

Count on Concrete PAVEMENT

ACPA

Changes have occured in Materials & Construction

Demand to build it faster, under traffic & last longer



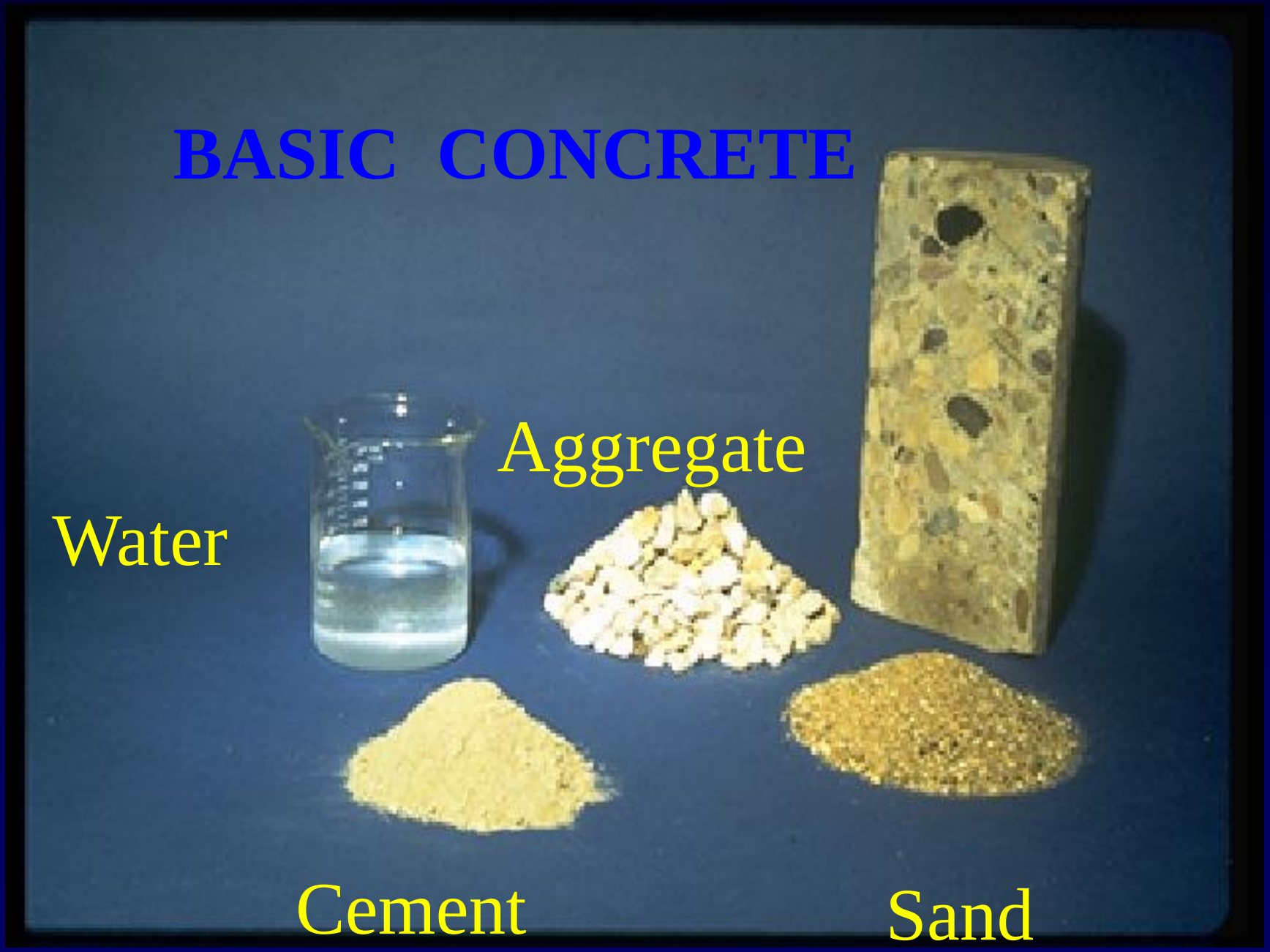
Central Mix Batch Plant


COMACO
GHP 2800

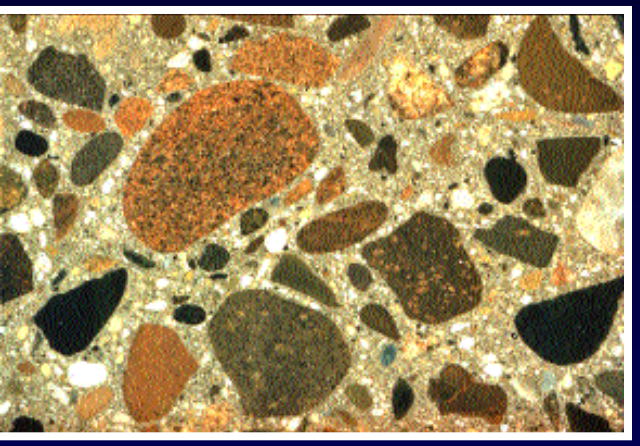

Wirtgen


SP 25
Wirtgen

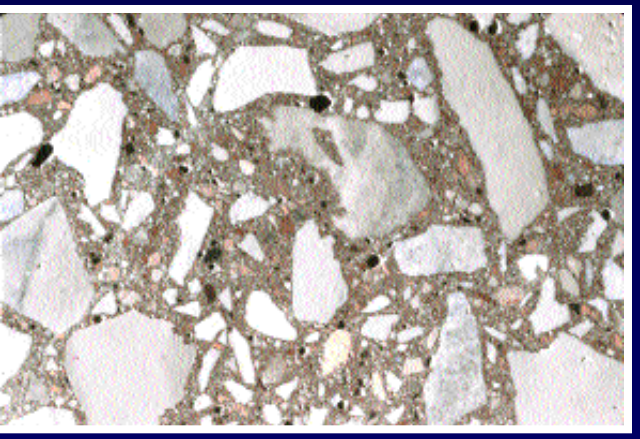
BASIC CONCRETE



Cross Section of Hardened Concrete

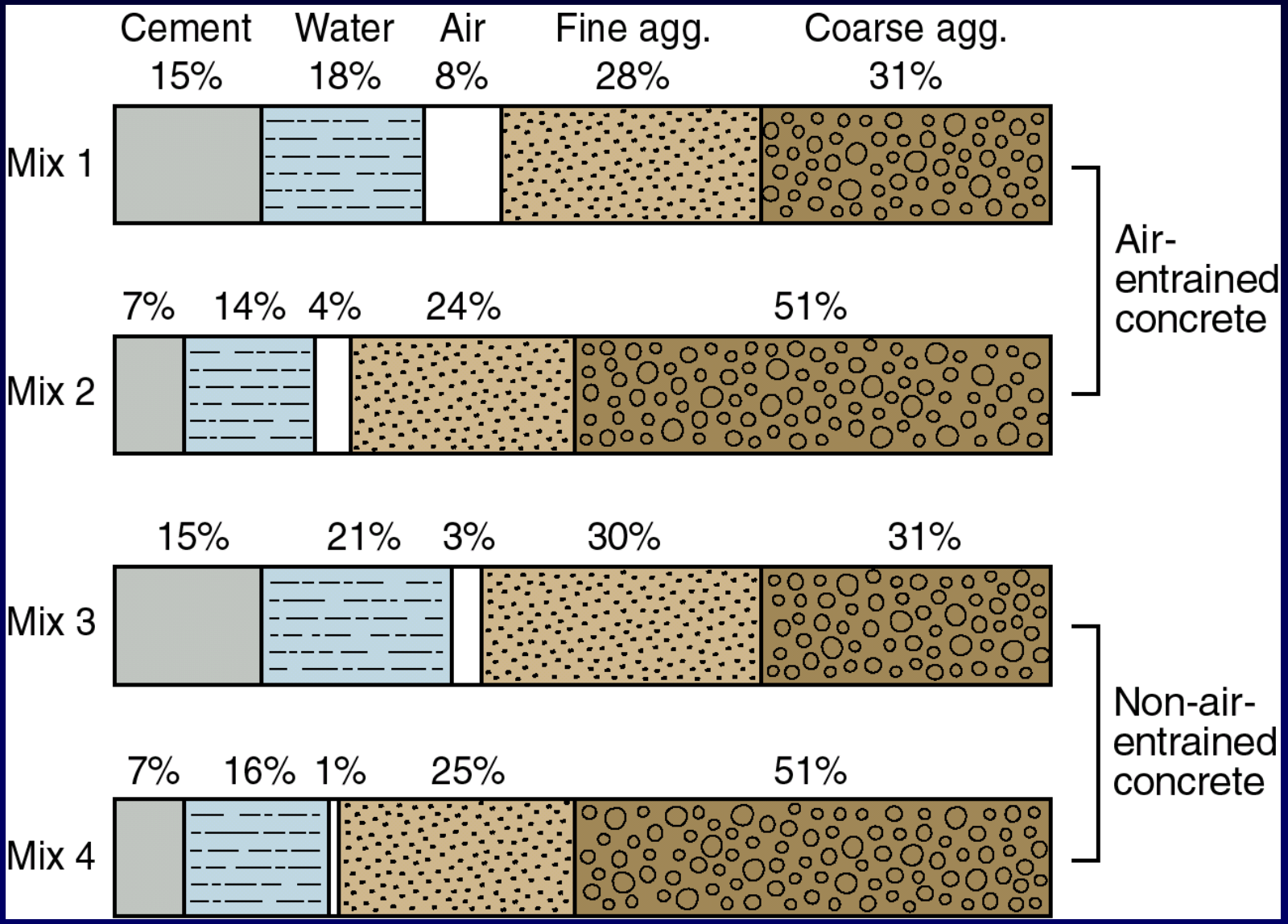


Concrete made with siliceous rounded gravel



Concrete made with crushed limestone

Range in Proportions




GOMACO
GHP 2800
Quality Control Check

Consider the Difference Between Lab and Production Concrete

Although all batches are intended to be exact duplicates, this is not so in practice

Larger Measuring Tools
More Rapid Production

Concrete Mix Design Variance and Corrections

- Mix Design Sheet includes a number of variables that can affect the quality of concrete
  - Water Cement (W/C) Ratio
  - Aggregate info
  - Air Entrainment %
  - Unit Weights (Yields)

Design Factors			Design Factors (cont.)		
Test Batch Size	27	cuft	Air Content	6.50%	
Cement Content	470	#/cy	Fine Agg/total Agg	47.00%	
Fly Ash Content	70	#/cy	Air Entr. Content	2.50	oz/cyd
W/C ratio	0.420		Admix #1 Content (WR)	4.00	oz/cwt Cemt.

Material	Size/Type	Source	Bulk S.G.(SSD)	Absorb.	Moist.
Cement	Type 1	lone STAR	3.15	---	---
Fly Ash	Class C	ROCKPORT	2.74	---	---
Fine Agg.	#23 Sand	M.M.KY.AVE.	2.68	0.85%	1.00%
Coarse Agg.	#8 Stone	M.M.WAVERLY	2.65	0.95%	4.00%
Air Entrmnt.	Dairavair 1400	WR GRACE	---	---	---
Admix. #1	WRDA 82	W.R.GRACE	---	---	---

Water Weights for 1 CYD (in pounds)	
Free Water	52.01
Mix Water	174.79
	=========
Total Water	226.80

Aggregate Weights for 1 CUYD (in pounds)	Fine	Coarse
SSD	1,478.44	1,648.51
Dry	1,465.97	1,633.00
Wet	1,480.63	1,698.32
Free Water	2.20	49.81

Batch Weight for:	1 Cyd	1 Cft	27.0 Cft
Cement	470 #	17.41 #	470.00 #
Fly Ash	70 #	2.59 #	70.00 #
Mix Water	175 #	6.47 #	174.79 #
Fine Aggregate	1,481 #	54.84 #	1,480.63 #
Coarse Aggregate	1,698 #	62.90 #	1,698.32 #
Air Entrainment	2.5 oz	0.093 oz	2.500 oz
Admix #1 (WR)	21.6 oz	0.800 oz	21.600 oz
	==========	========	========
Total	3,894 #	144.21 #	3,893.75 #

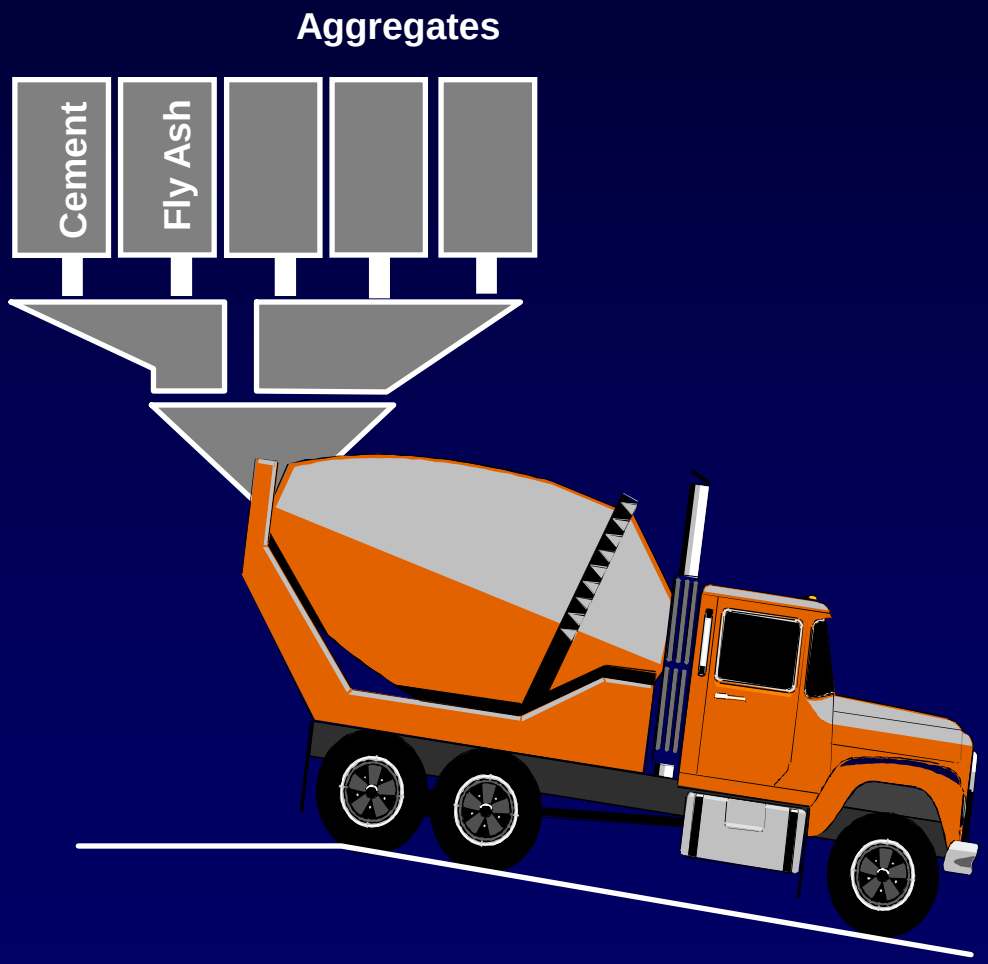
Batching

Batching/Mixing

Course aggregate & sand being transferred to aggregate bin

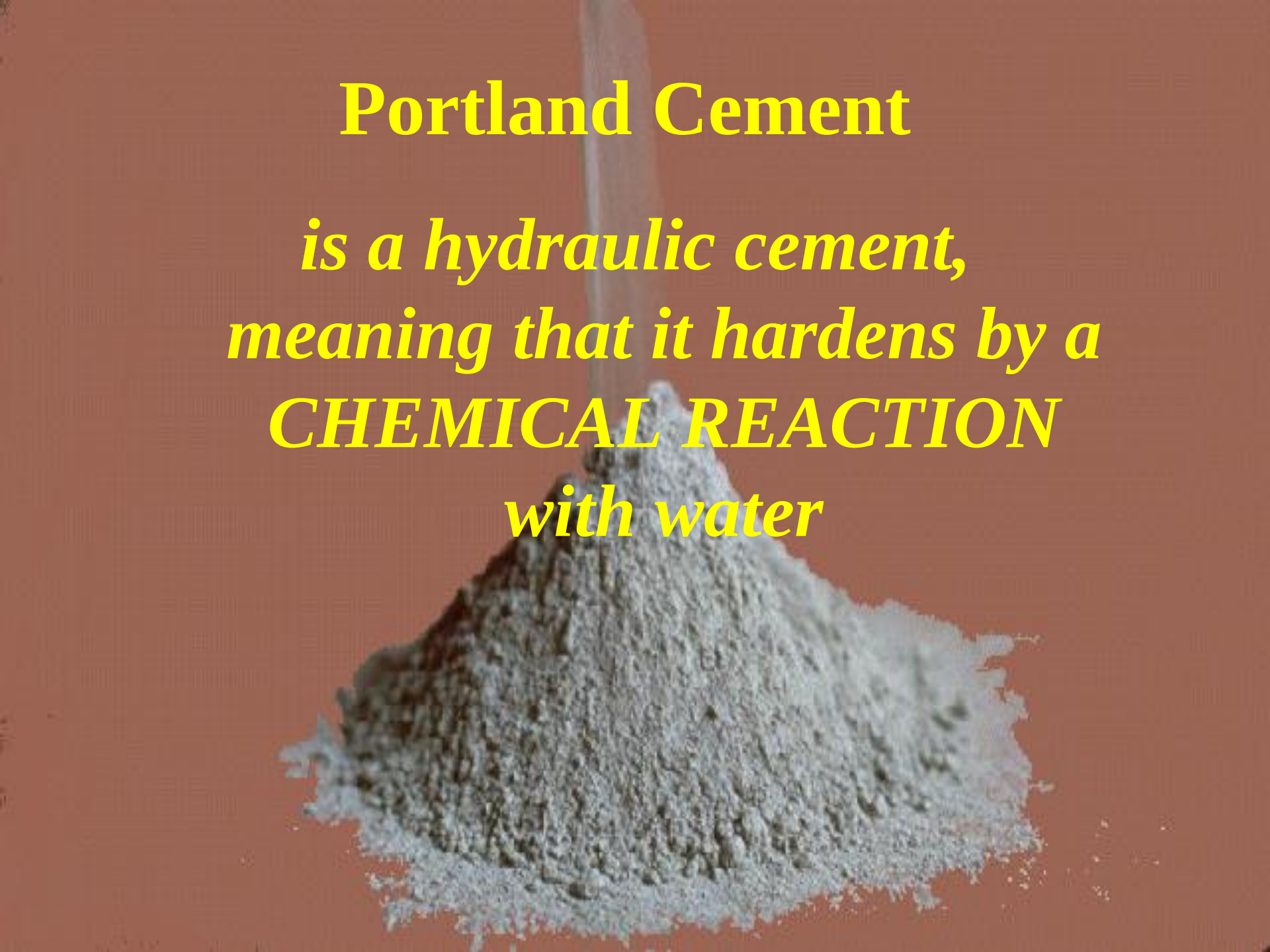
Central Mix Batch Plant

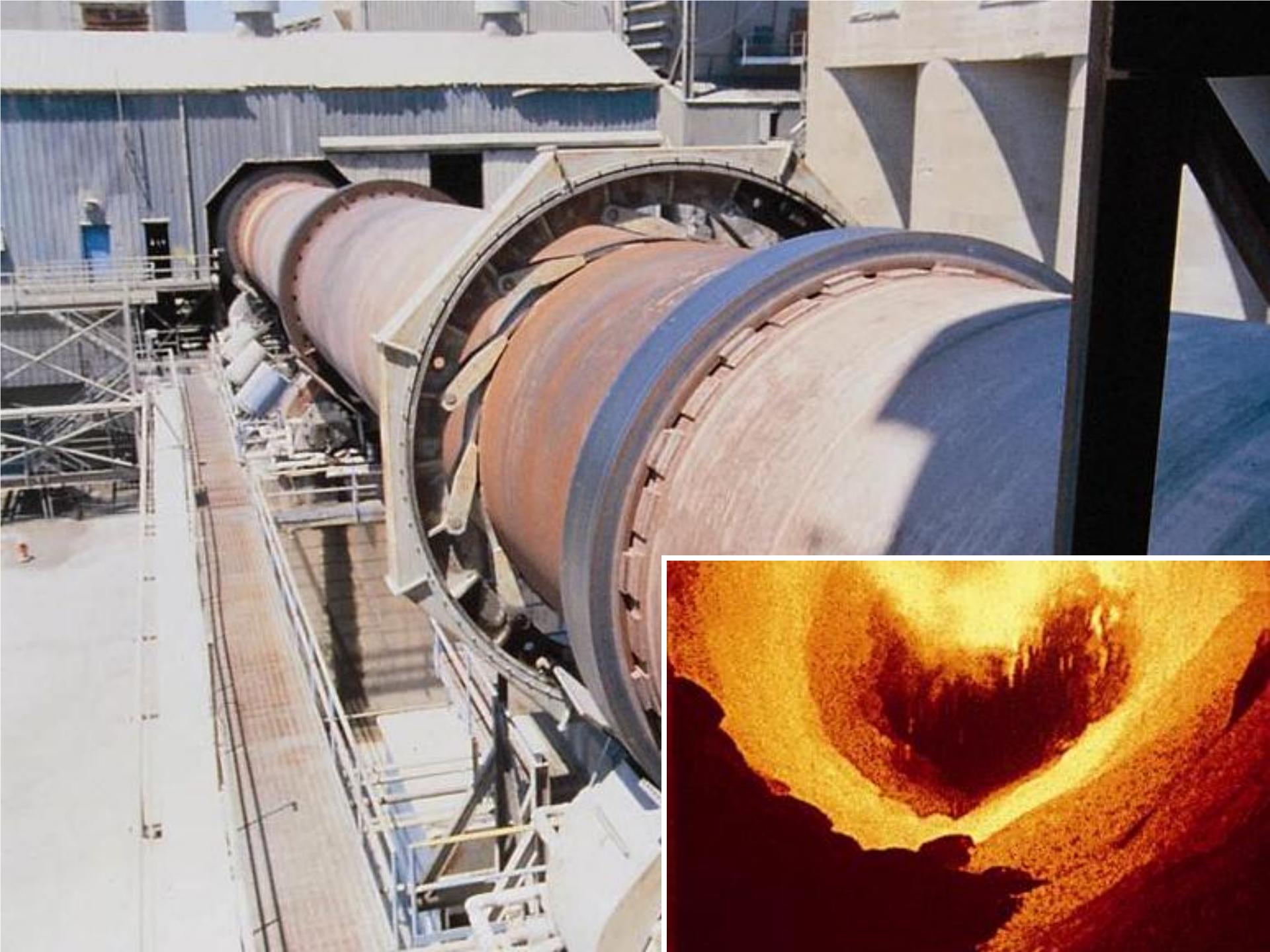
Truck Mixed Concrete



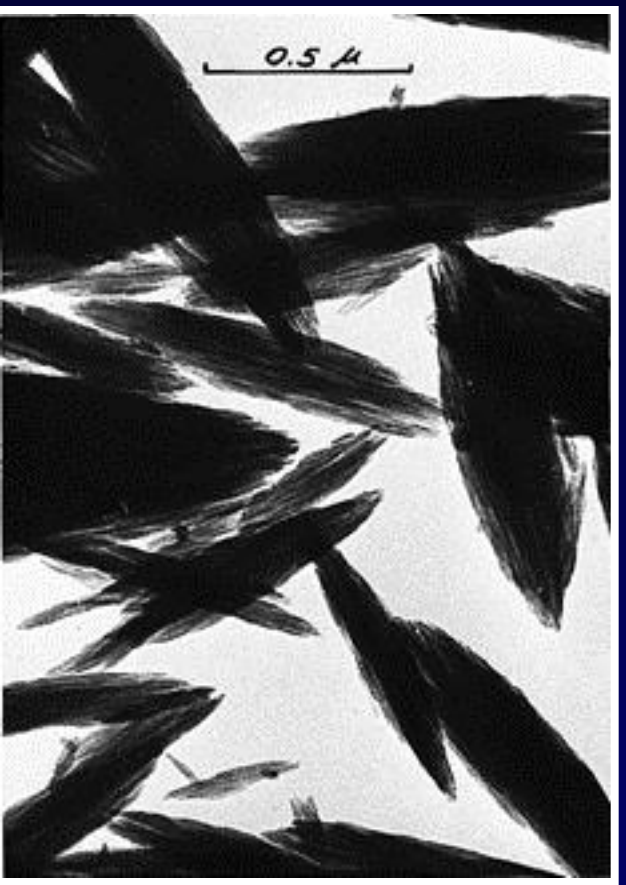
Portland Cement

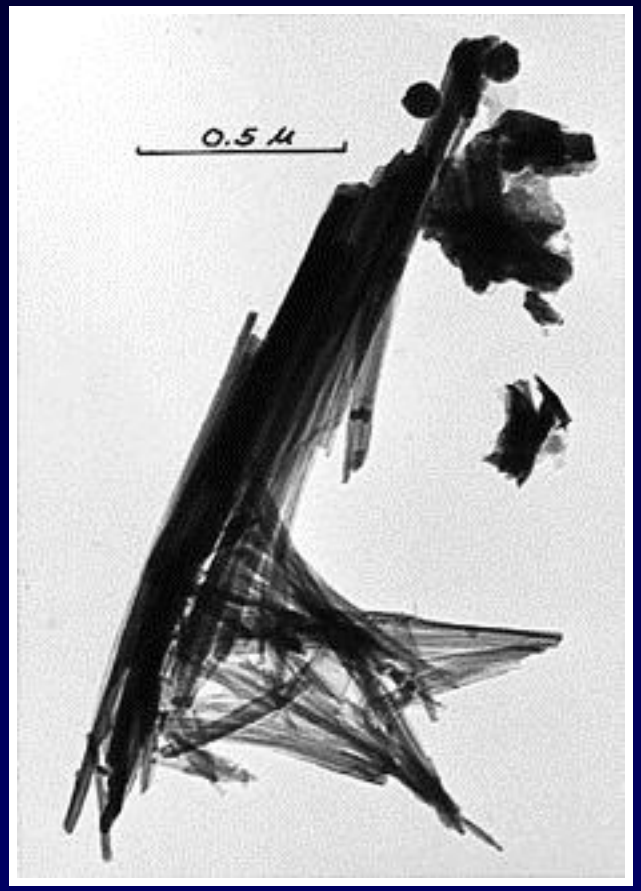
is a hydraulic cement, meaning that it hardens by a CHEMICAL REACTION with water

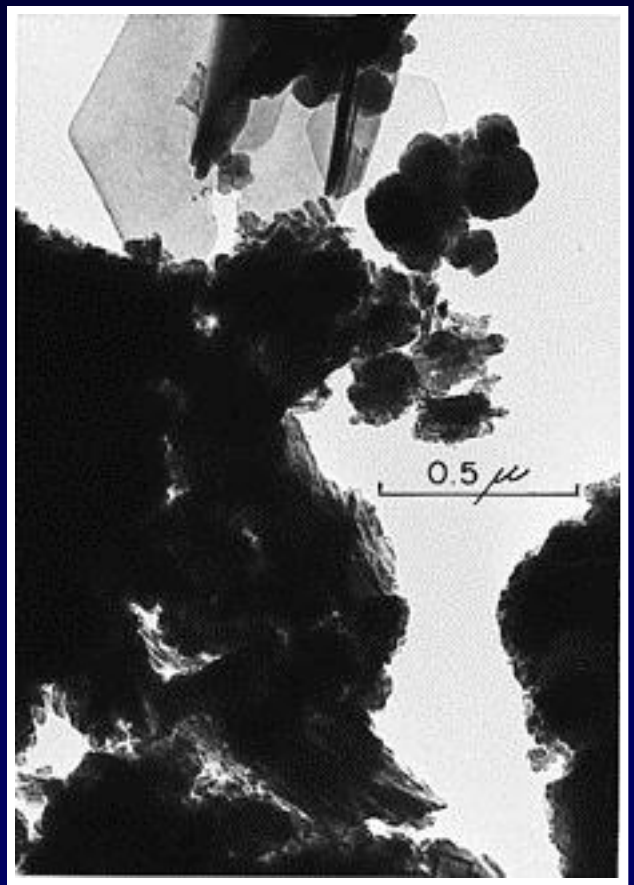




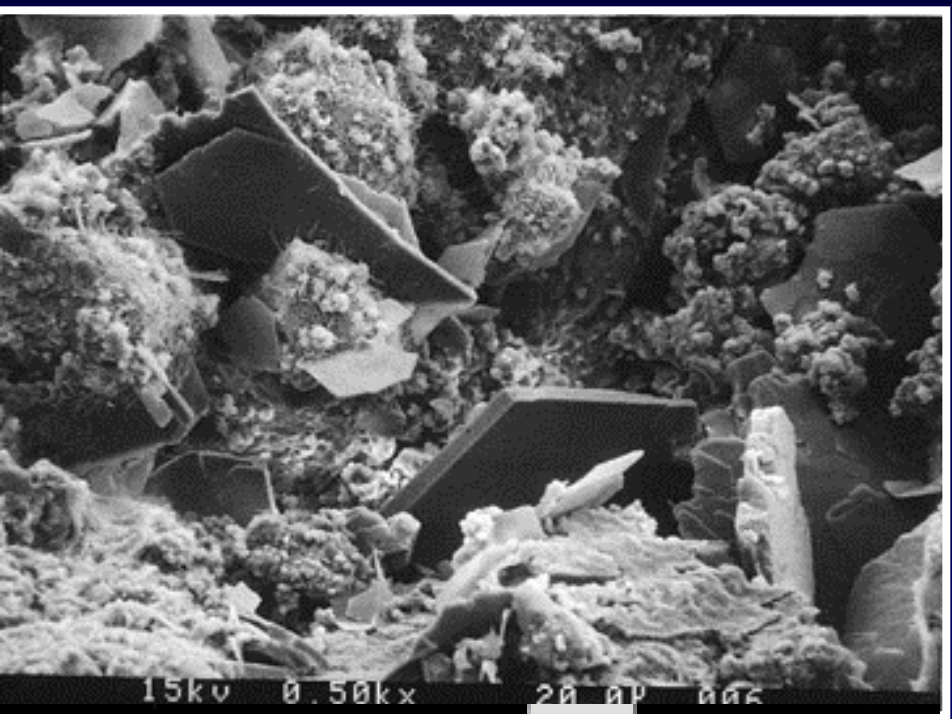
Hydration Products

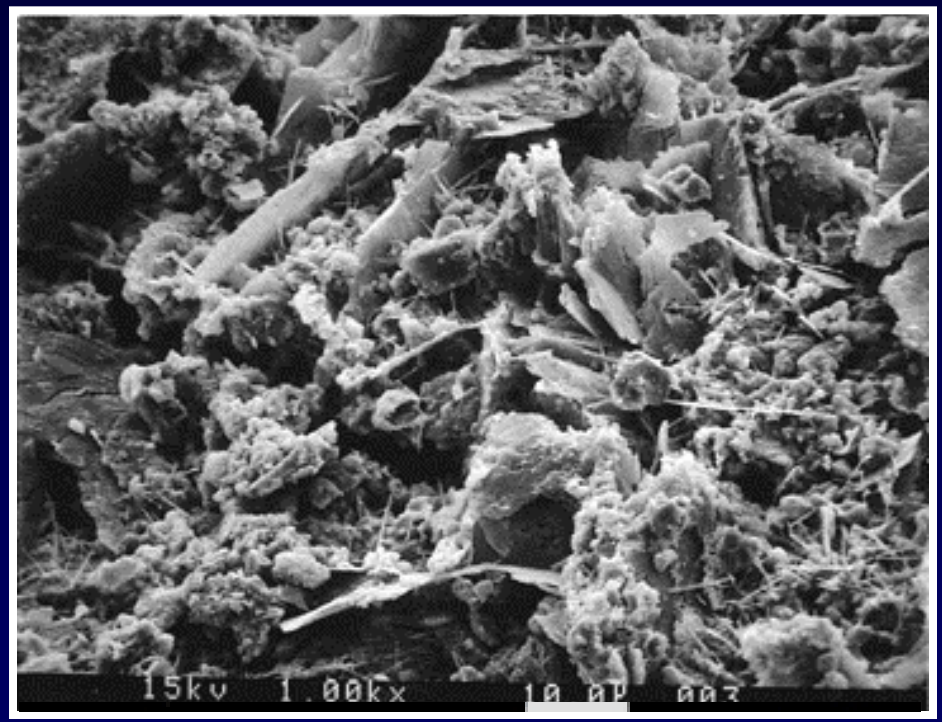






SEMs of Hardened Cement Paste





Cement and Its Impact on Concrete Performance

Module 1 - Cement's Role in Sustainability

Module 2- Cement Manufacturing

Module 3- Types and Applications of Cement

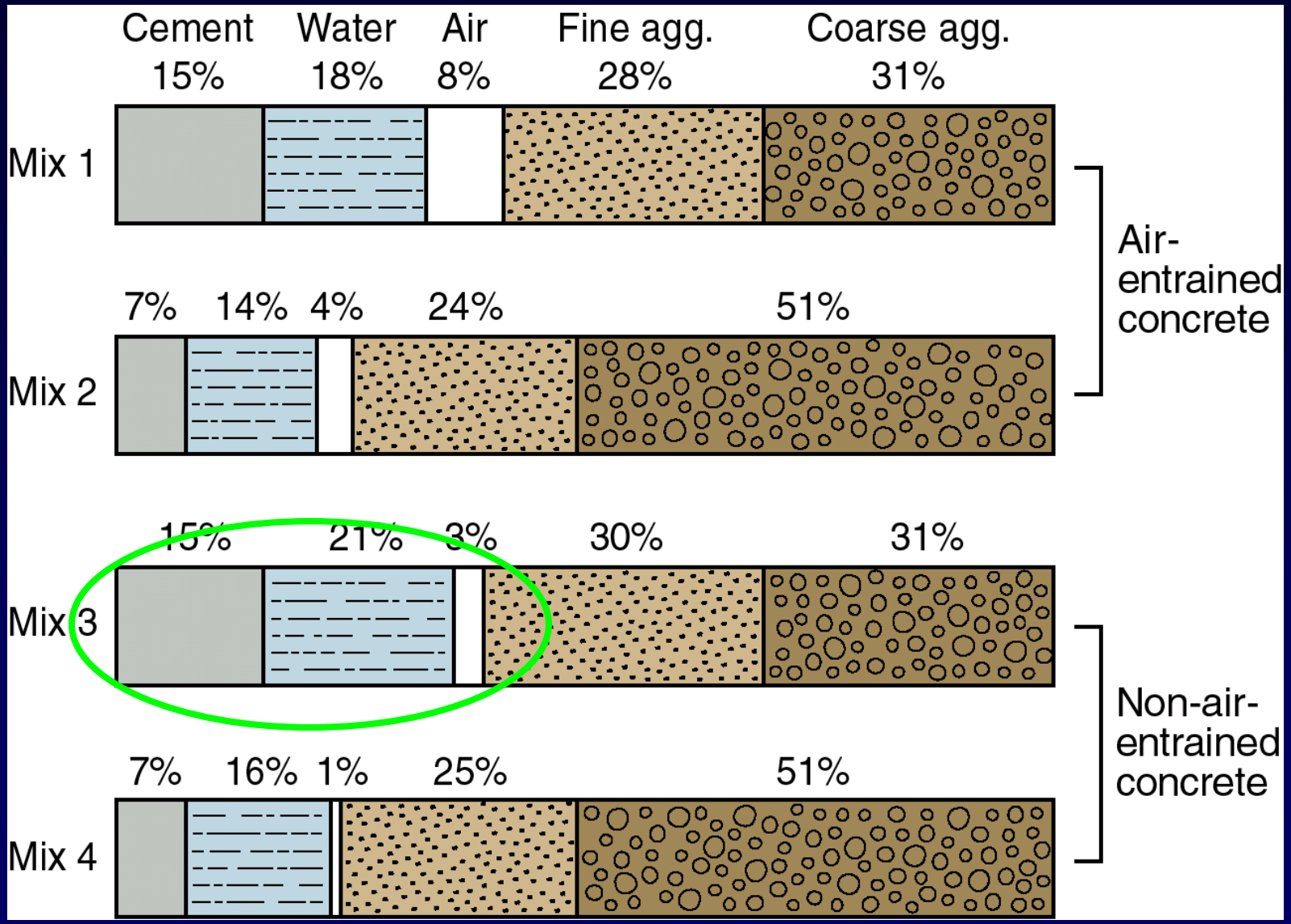
Module 4- Cement Characteristics

Module 5- Impact of Cement on Concrete Properties

Module 6- Abnormal Reactions and Compatibility of Materials with Cement

If you work with concrete, you need to understand cement.

Cement Paste



Aggregate Gradation Affects

- **Workability**
- **Pumpability**
- **Economy**
- **Porosity**
- **Shrinkage**
- **Durability**

Admixtures

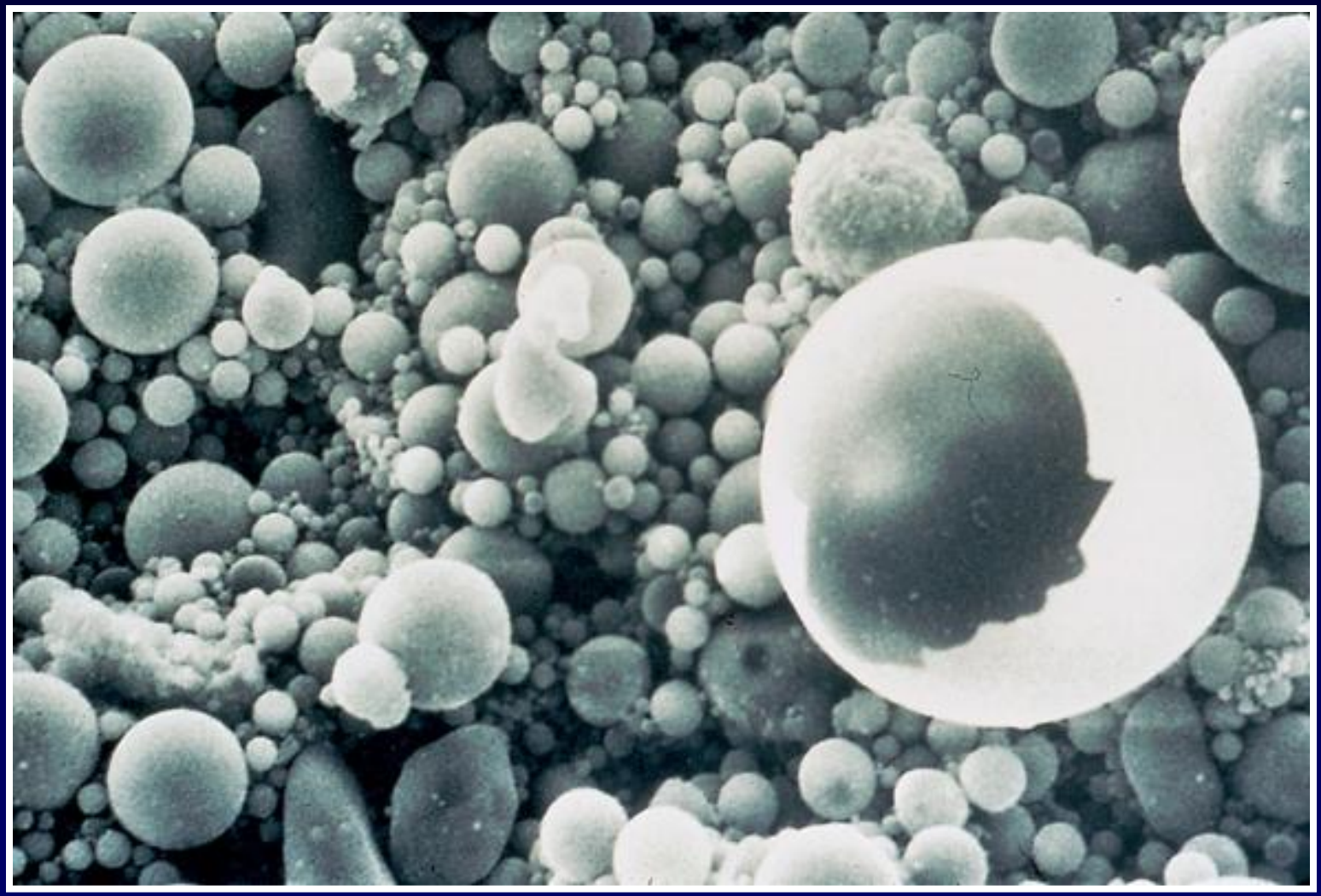
- Air-entraining admixtures
- Water-reducing admixtures
- Plasticizers
- Accelerating admixtures
- Retarding admixtures
- Hydration-control admixtures
- Corrosion inhibitors
- Shrinkage reducers
- ASR inhibitors
- Coloring admixtures

Pozzolans

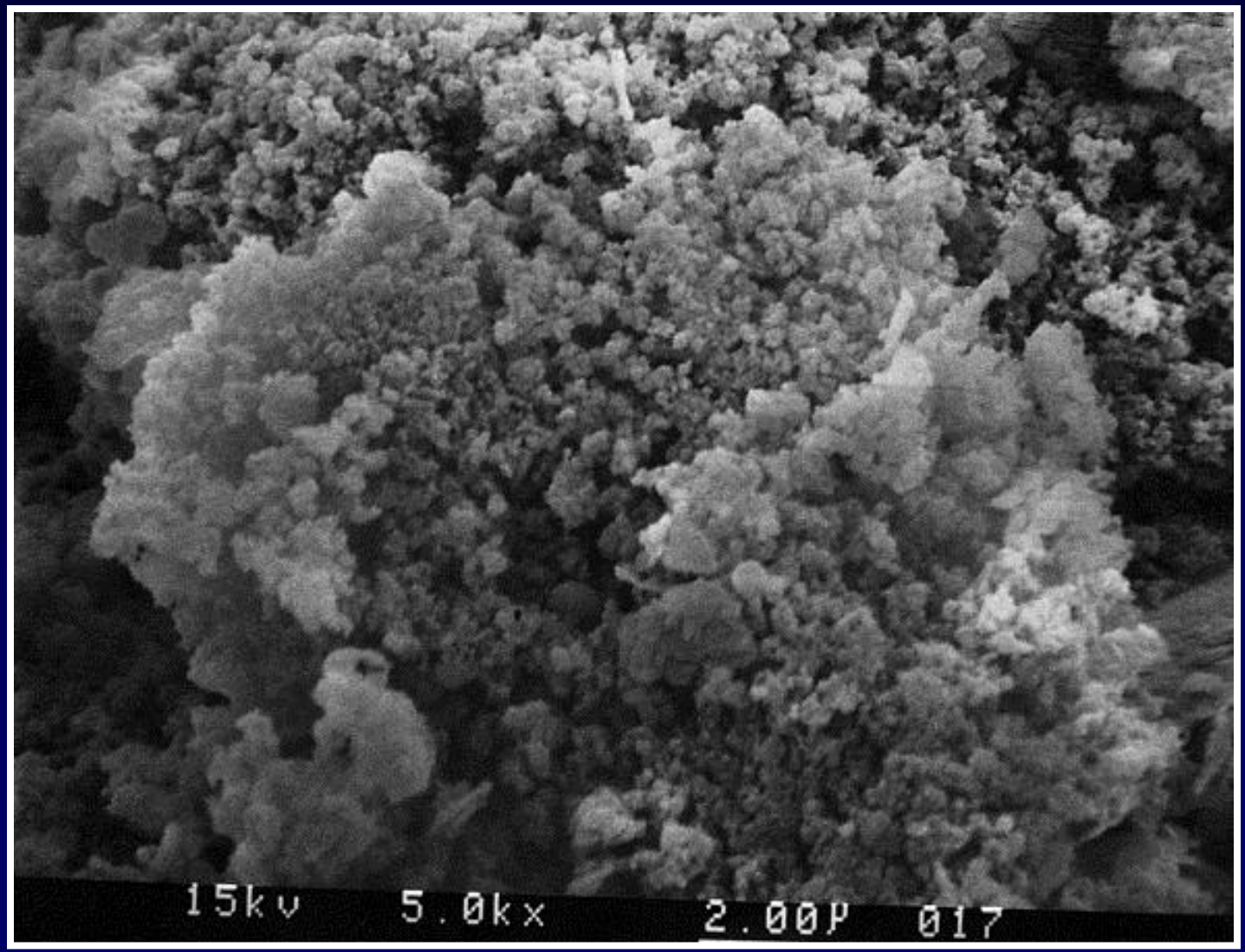
- Fly Ash
- Microsilica – silica fume
- GGBFS – ground granulated blast furnace slag


GGBF slag
grade 120
Portland Cement
Type I
Fly Ash
class C

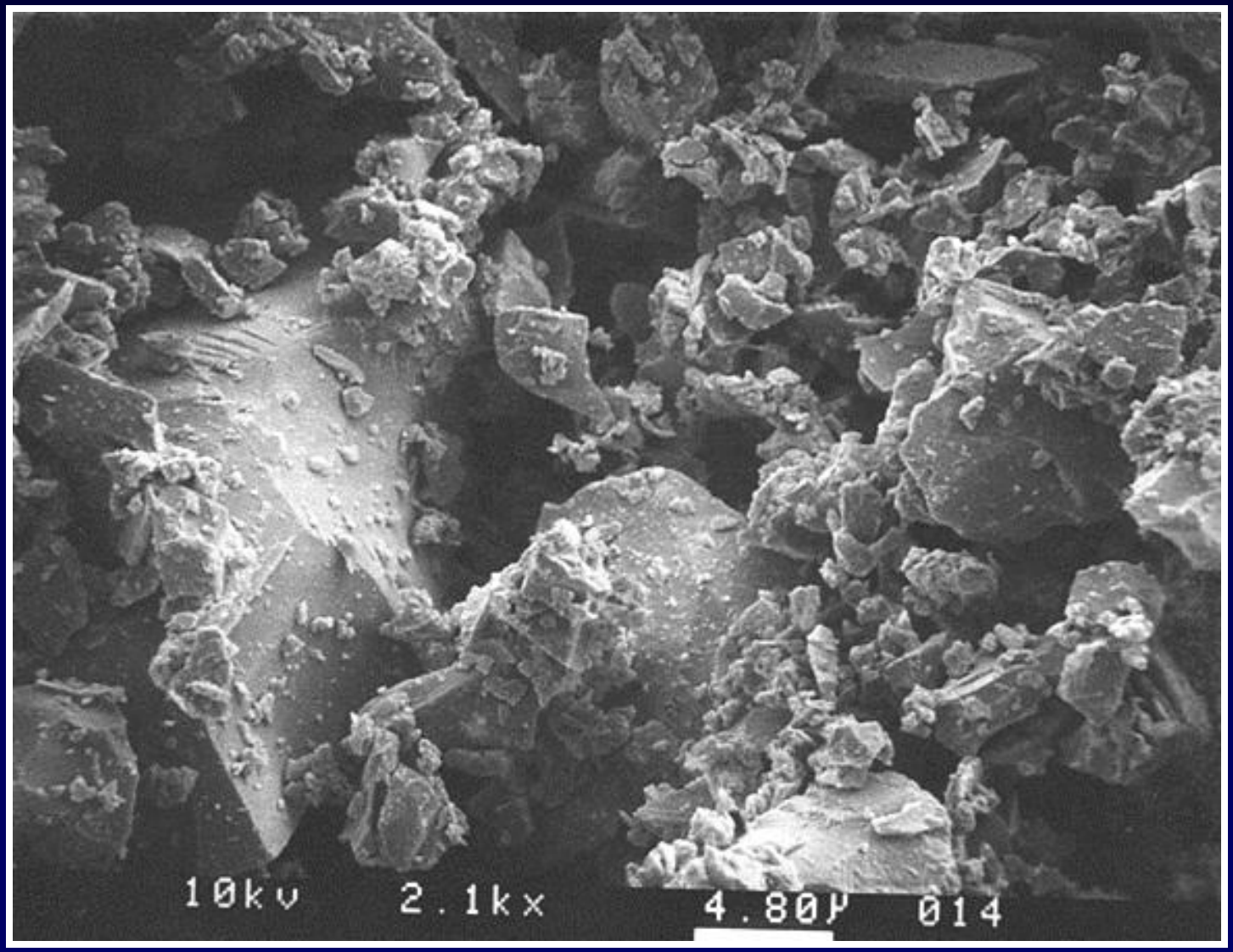
SEM of Fly Ash Particles



SEM of Silica Fume Particles



SEM of Slag Particles



CEMENT + WATER

$CS(glue) + Ca(OH)_2 + H_2O$

$$Ca(OH)_2 + H_2O + \text{Pozzolan}$$

$$CS(\text{glue}) + H_2O$$

Types of Fly Ash

- Class F
- Class C

Class F Fly Ash

- Eastern Coal
- High Sulfur Content
- LOI varies with source
- No cementitious properties

Class C Fly Ash

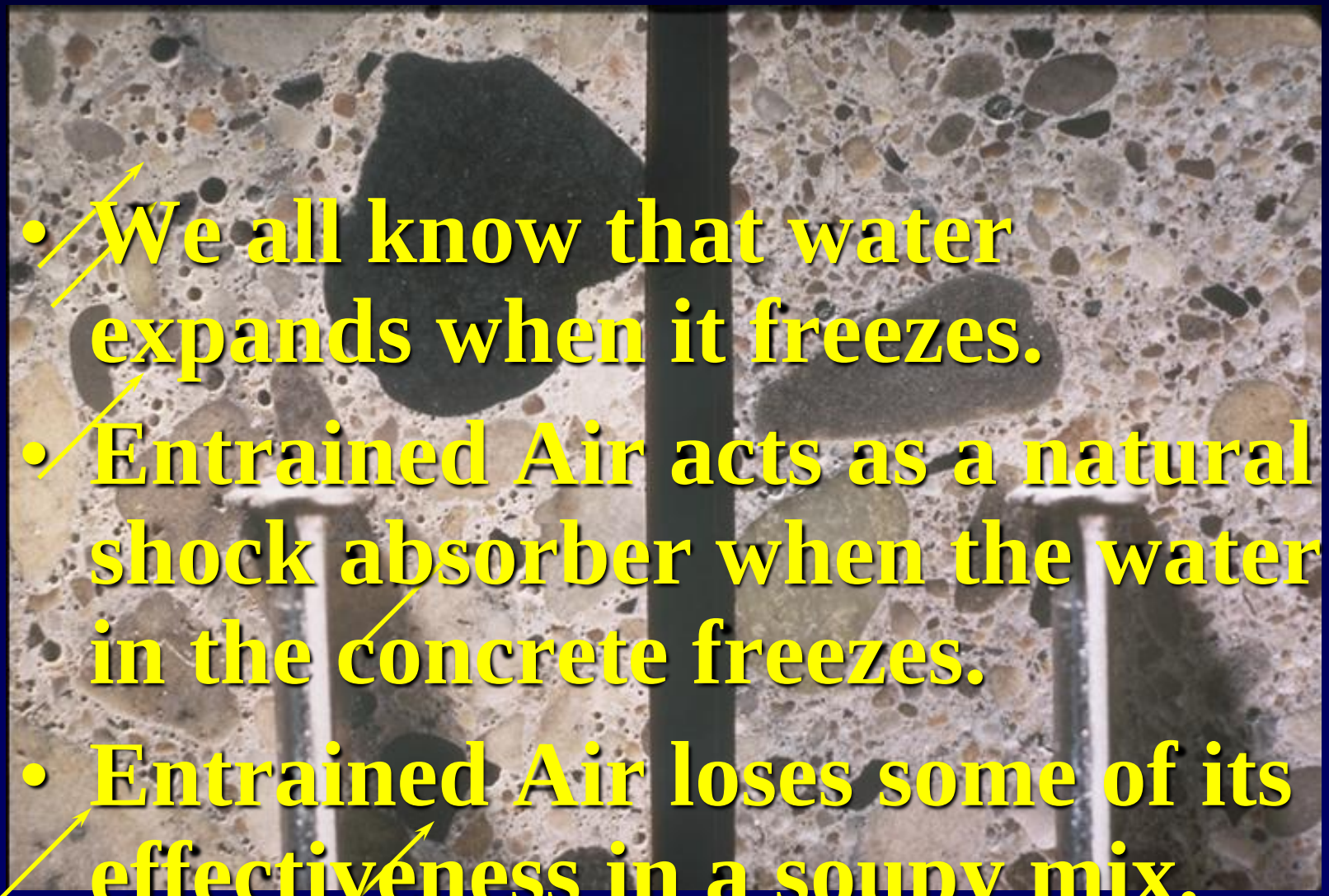
- Western Coal
- Low Sulphur Content
- Low LOI
- Consistent LOI
- Slightly cementitious

Effects of Fly Ash

- Placability
- Durability
- Time of Set

Air Entraining Admixtures

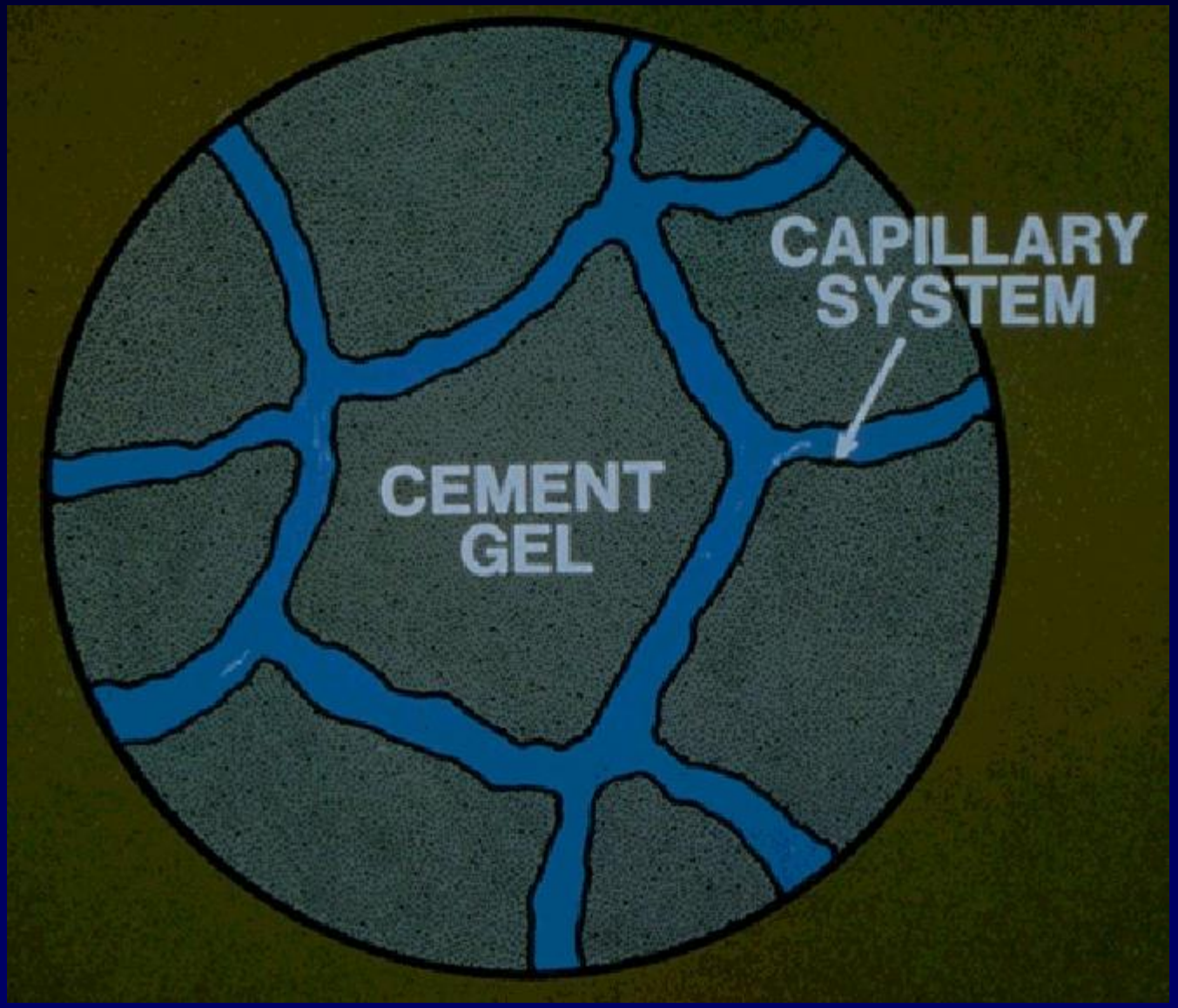
Air Entrained Non-Air Entrained

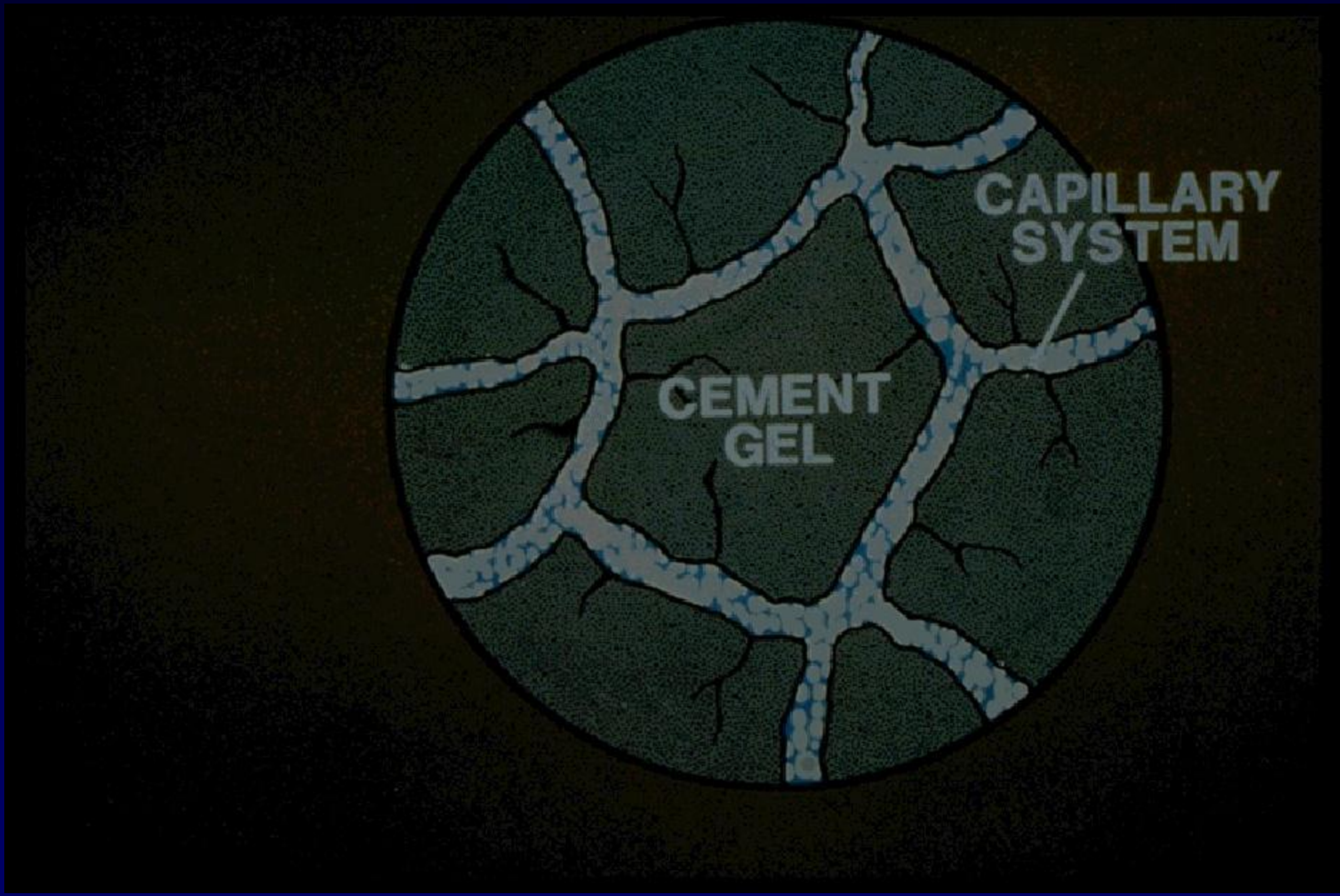


- **We all know that water expands when it freezes.**
- **Entrained Air acts as a natural shock absorber when the water in the concrete freezes.**
- **Entrained Air loses some of its effectiveness in a soupy mix.**

Air Entrainment/ Hardened Concrete

- Better freeze-thaw resistance
- Increased watertightness
- Reduced concrete weight


CAPILLARY
SYSTEM
CEMENT
GEL


CAPILLARY
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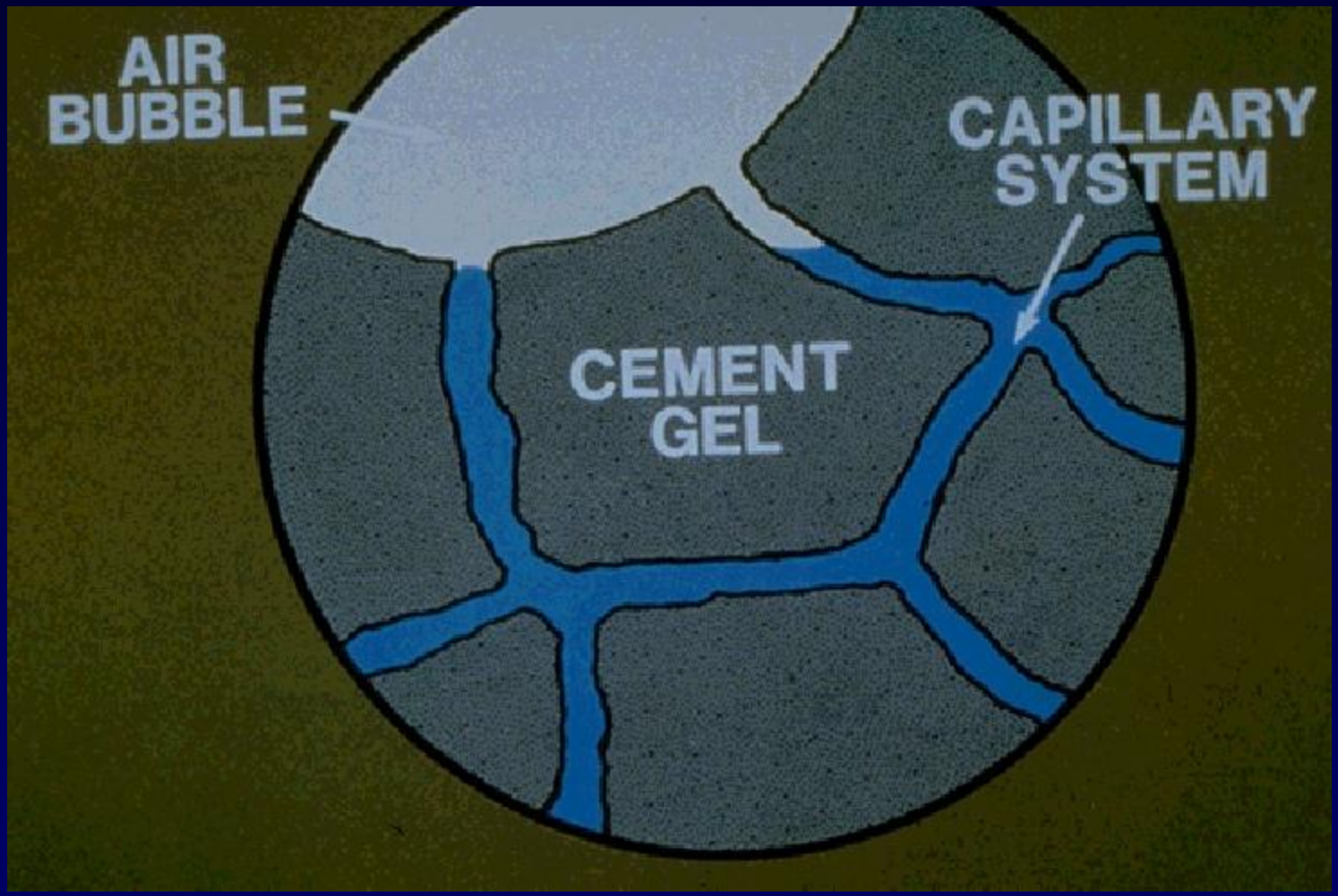
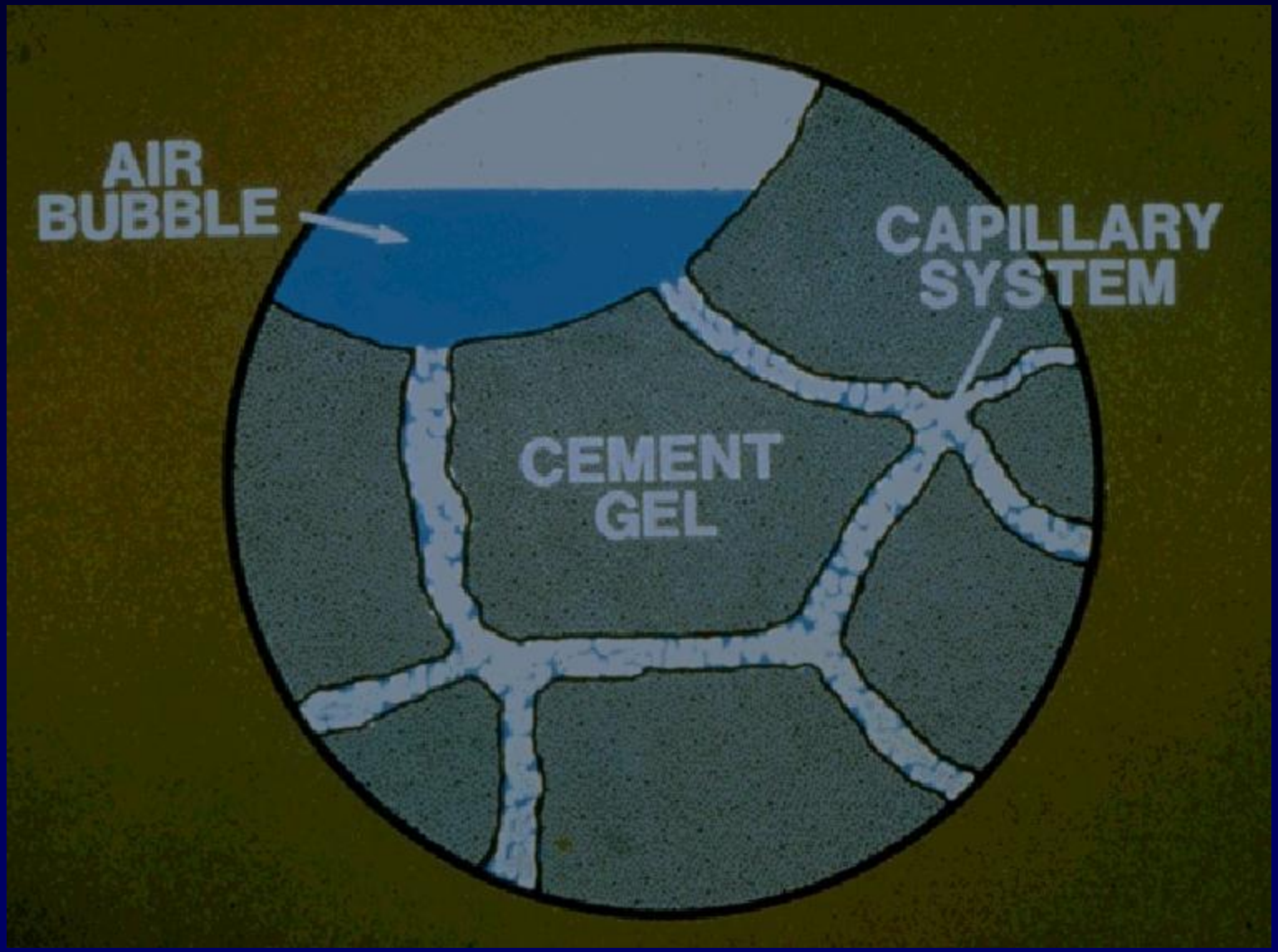

AIR
BUBBLE
CAPILLARY
SYSTEM
CEMENT
GEL


AIR
BUBBLE
CAPILLARY
SYSTEM
CEMENT
GEL

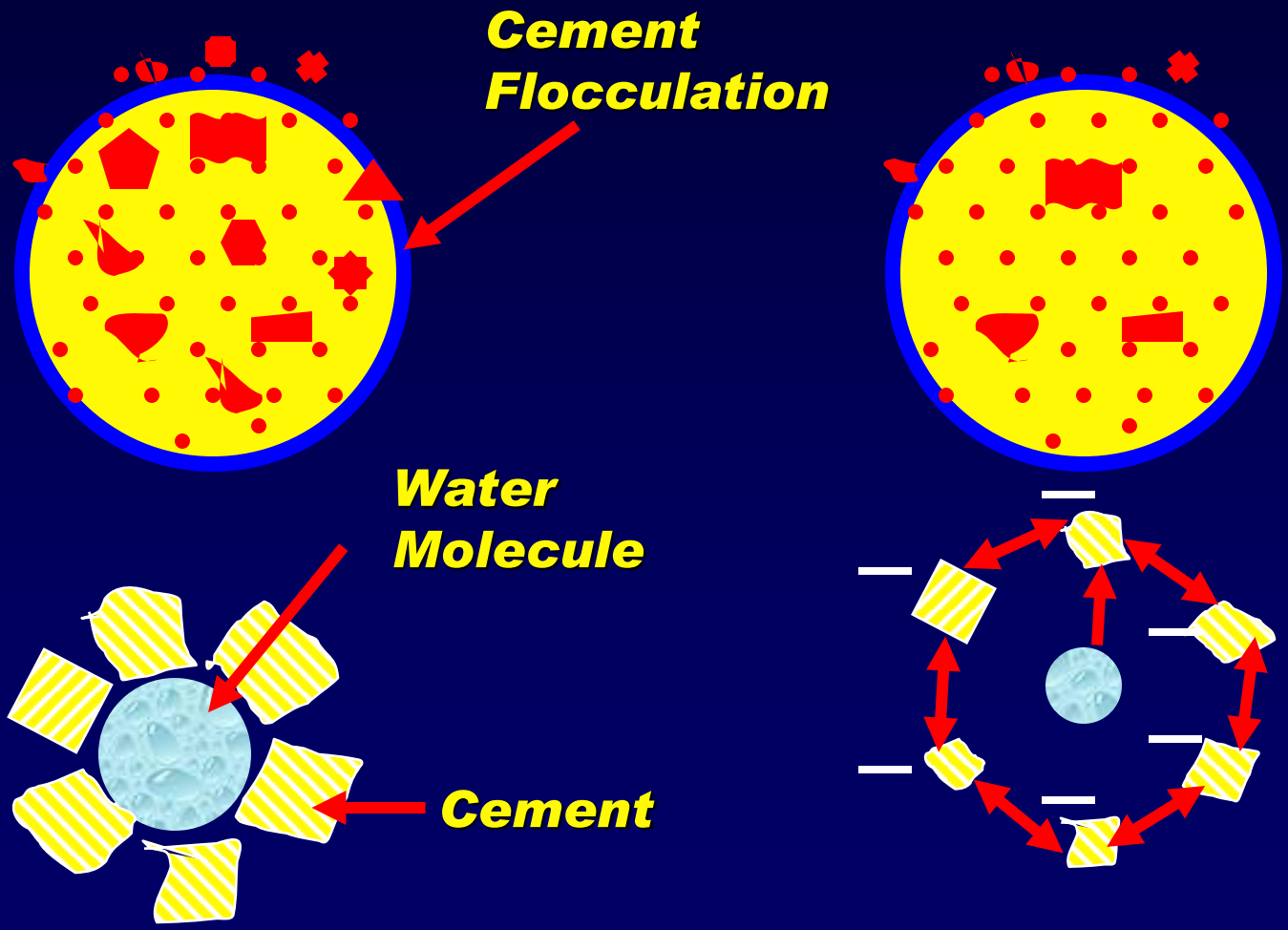
Water Reducing Admixtures

Water Reducing Admixtures
What Are They?

- Admixtures that either ***increase slump of freshly-mixed mortar or concrete without increasing water content*** ***OR*** ***maintain slump with a reduced amount of water***, the effect being due to factors other than air entrainment.

(ACI 116.R-2)

Water Reducer Chemical Action



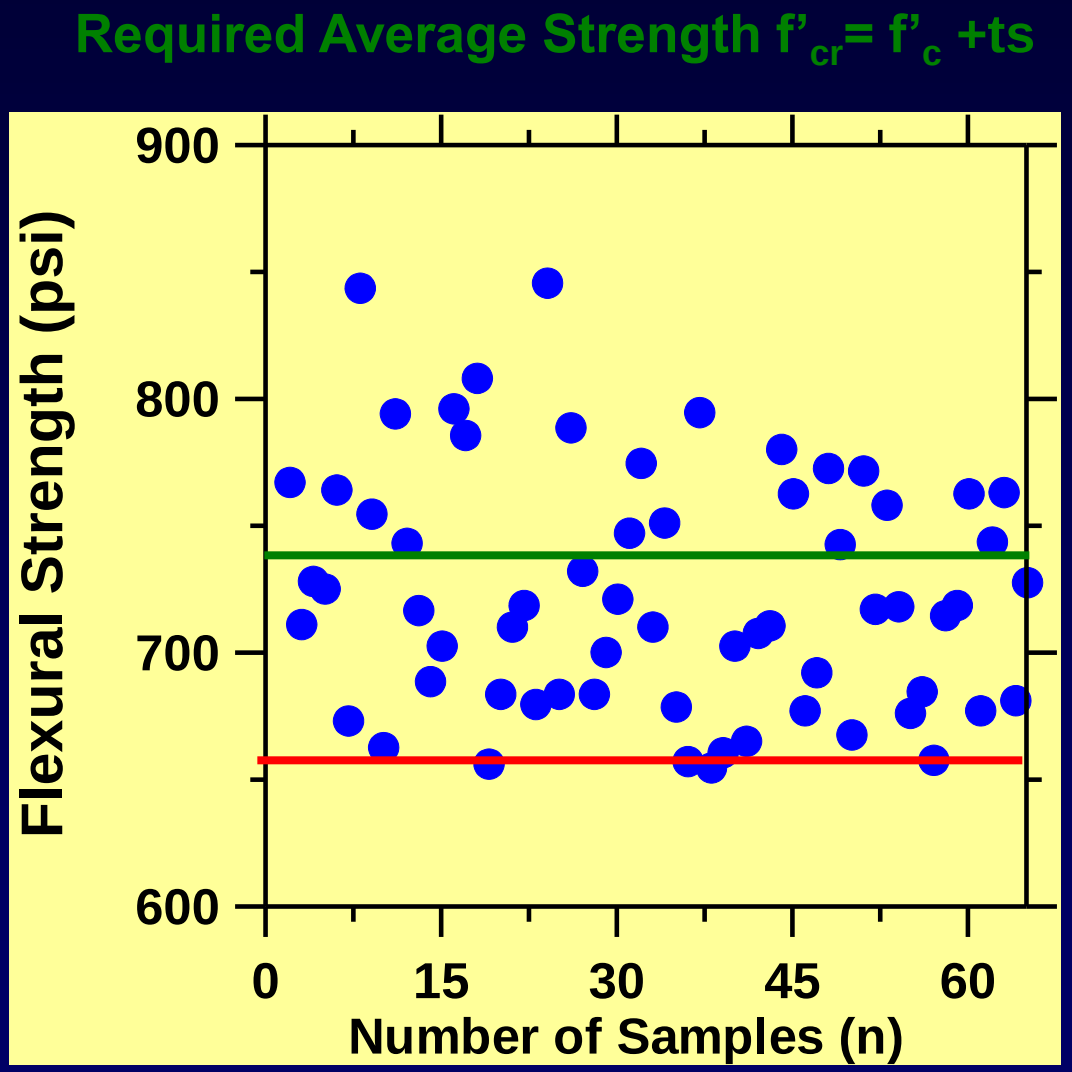
Quality Control

Quality Control is an Active Process

- Tests provide information
  - to better understand material
  - to verify production as compared to target and set points
  - to make adjustments

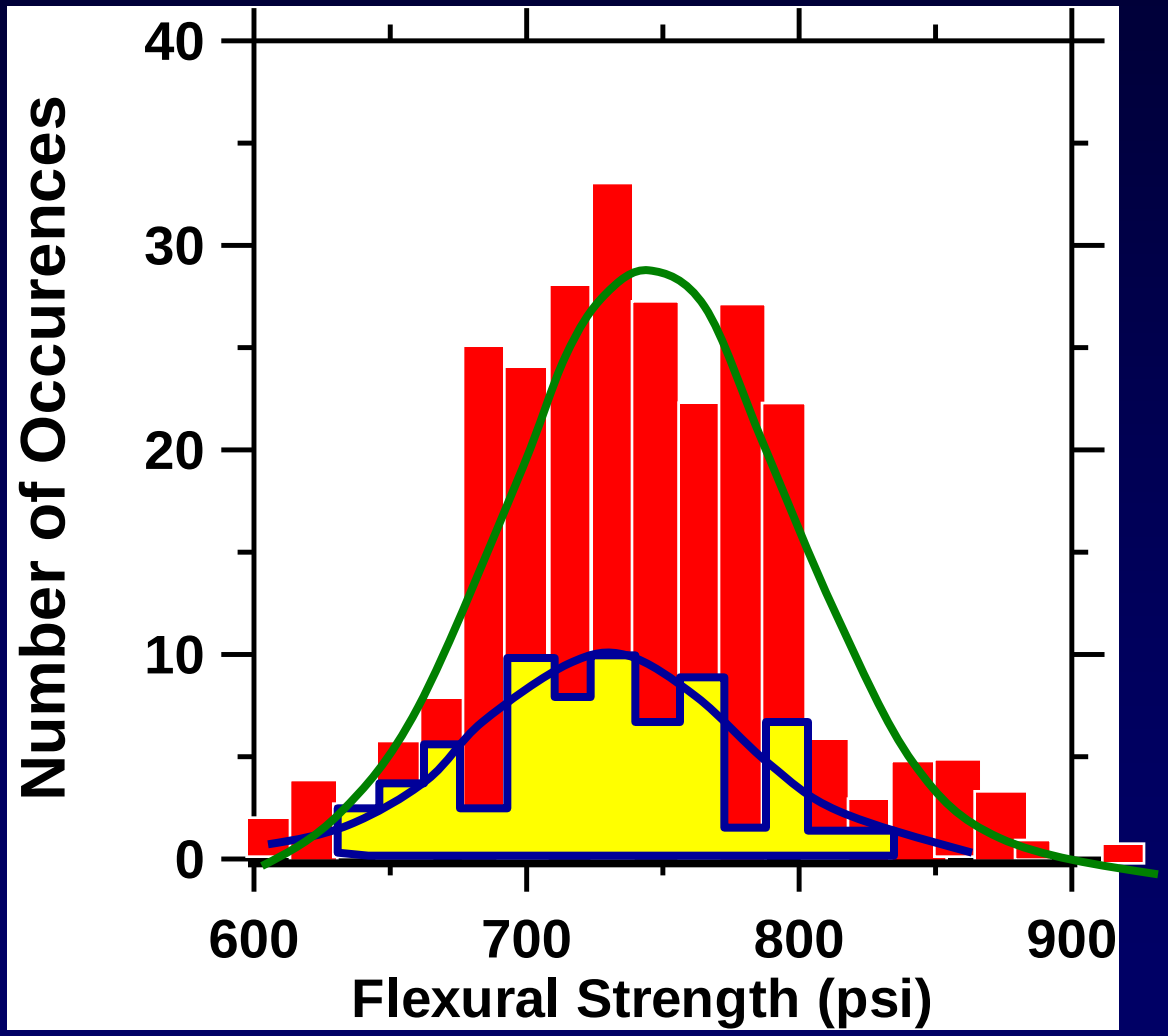
Quality Control Charts

- Economical method based on statistics and probability
- Provide a method to assess on a continuous basis
- Graphical Representation



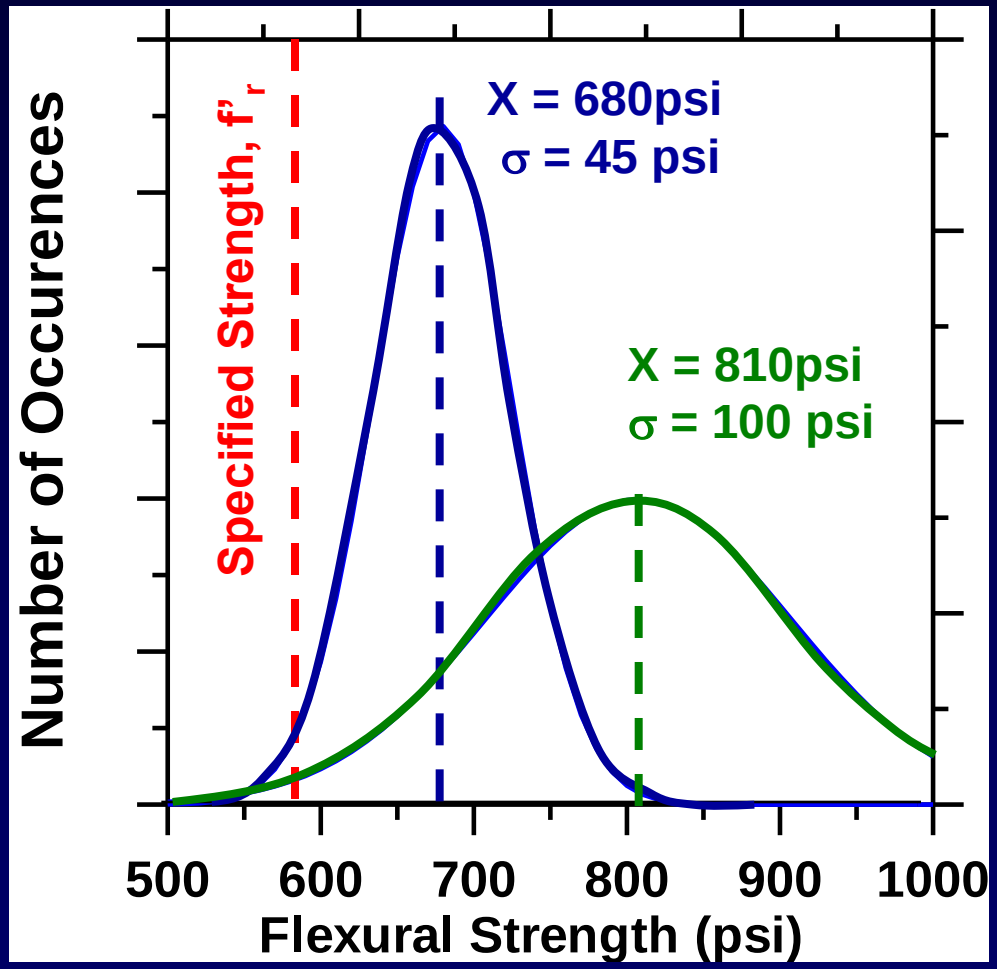
Proper QC Helps to Avoid Big Surprises in QA

- Here we see samples tested by the contractor in "their schedule"
- mean - 762 psi
- std dev – 49 psi
- When the agency tested
- mean - 752 psi
- std dev – 45 psi



What Are the Practical Implications of Having Tighter Quality Control

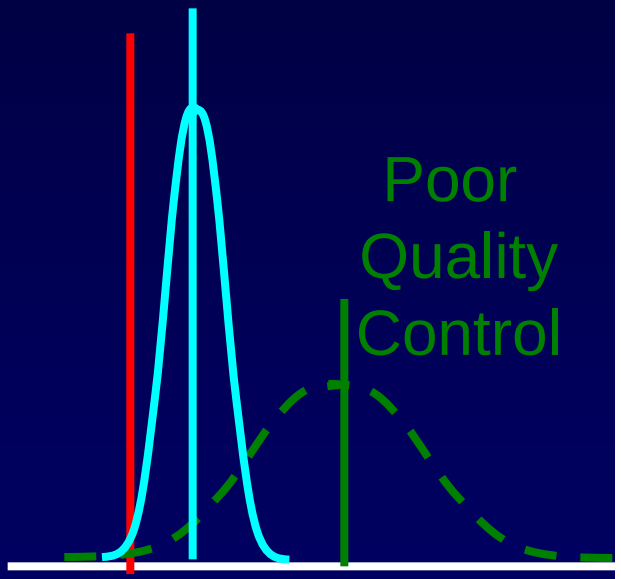
- We can not design structures based on the mean measured strength but we will use it for designing the mixture
- Assumption: 1/1000 tests are below the design strength (f'_r=570 psi)
- Consider two contractors with measured variation



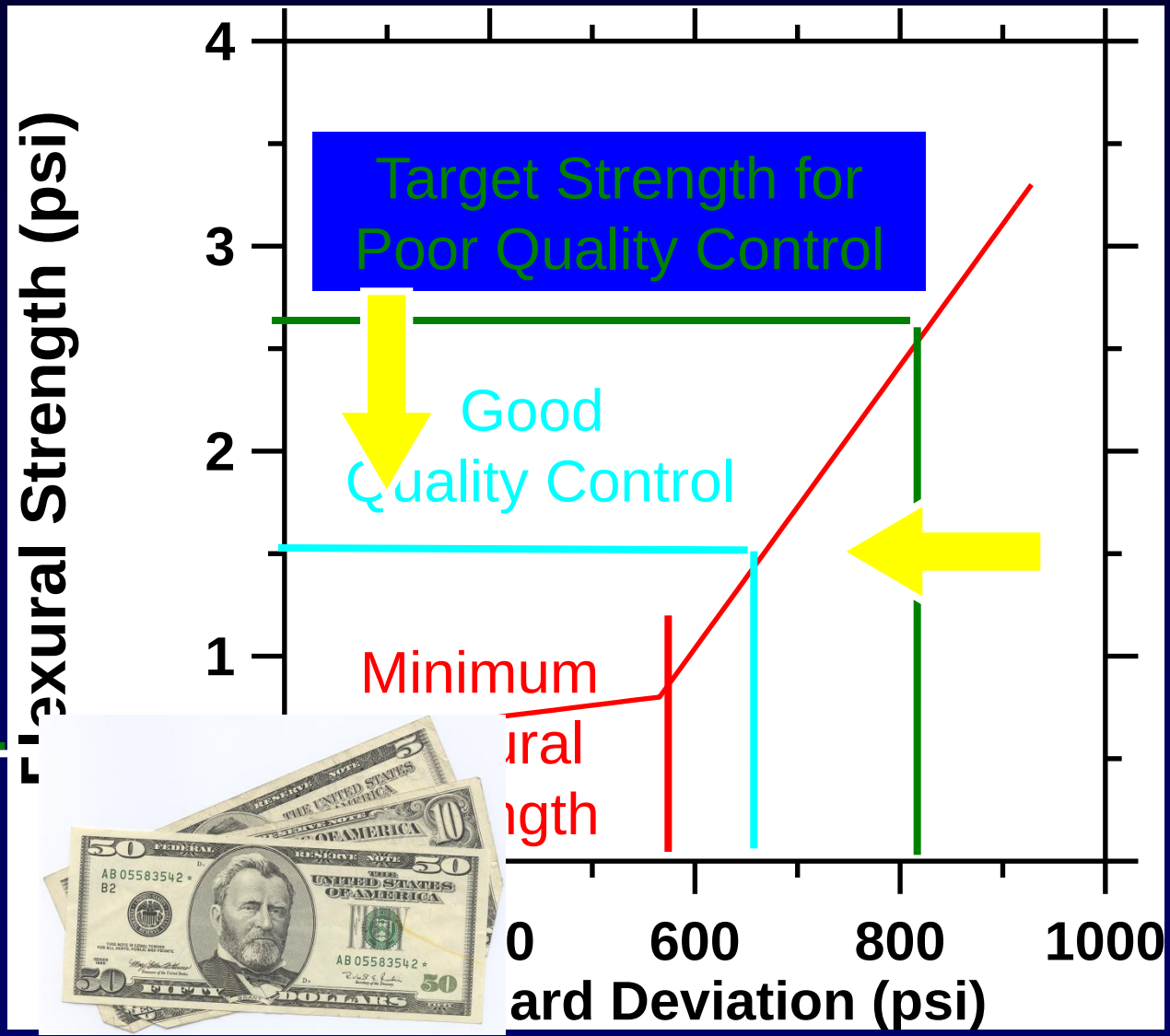
What Does Improving the Quality Control Mean in Real Life

Good Quality Control

Poor Quality Control



Minimum Quality Level
f'_r = 570 psi



Research – New Frontiers, Problem Solving

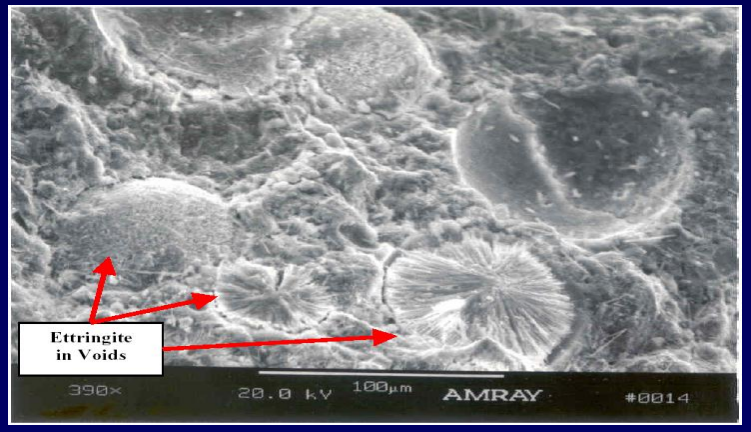
Premature Joint Deterioration

Premature Joint Deterioration

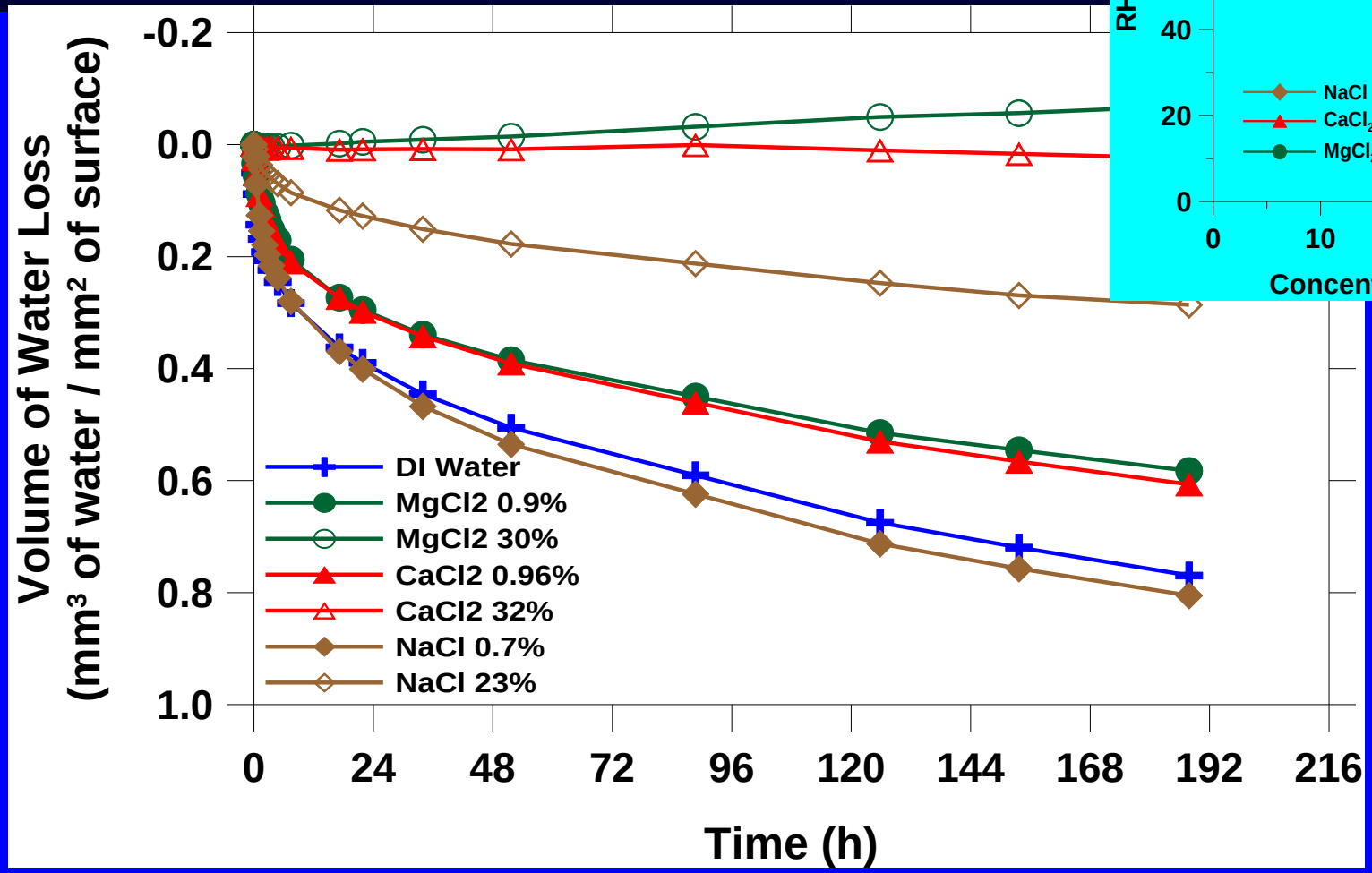
Premature Joint Deterioration

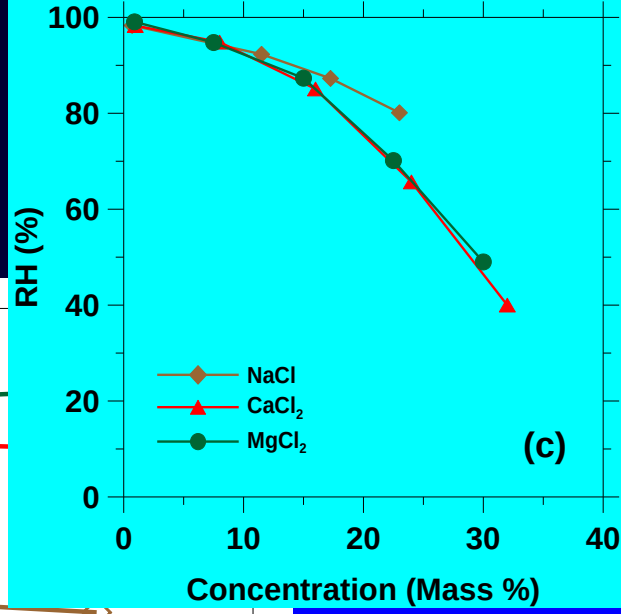
Premature Joint Deterioration

- Air voids filled with hydration products (secondary products)
- Secondary product (ettringite) in air entrained small bubbles



“Drying of Concrete





Spragg et al. submitted 2010

Slab –Silver Nitrate

23% NaCl	30% FreezeGard	32% $CaCl_2$	Water

No Sealer – 4 different Soaking Solutions (56 Days).
NaCl most penetrated, $CaCl_2$ Damaged Surface, and Water Shows No Penetration.

Freeze-Thaw Durability

- Concrete can experience significant damage due to freezing and thawing
- ASTM C666
  - procedure A (freeze and thaw in water)
- Monitor change in dynamic elastic modulus and mass

Freeze-Thaw Durability

Plain SME-PS Dose 1 SME-PS Dose 2 SBS

Additional Research Efforts

- Internal Curing of Concrete
- Using Recycled Crushed Concrete as Coarse Aggregate in Concrete
- Investigation of Deicing Chemicals Interaction with Concrete
- Use of Slag Aggregates & Slag Cements in Concrete – Impact on Durability Performance
- 30+ SACs/on going projects

Questions?

Information:

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